Design & Simulation of a Composite Gamma Detector with fast-Timing, Good Resolution, Efficieny & Tracking Possibilities

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Introduction

Conventionally HPGe detectors have been at the heart of a Gamma Detector Array, due to their excellent energy resolution (ΔE = 2 keV @ 1332 keV). However, the fast rise time from scintillator pulses have been exploited to perform timing measurements (Δt = 200 ps at 662 keV). Presently, LaBr3:Ce scintillators are attractive due to their excellent timing resolution as well as a reasonable energy resolution (ΔE = 20 keV at 662 keV). Therefore it is tempting to design a composite detector from a combination of HPGe and a $LaBr_3$:Ce, which besides providing a fast timing also has a reasonable energy resolution as well as efficiency, and also allows possibilities for tracking.

The proposed hybrid system would be configured using $LaBr_3$:Ce to provide an excellent timing information, backed by a HPGe, as a second layer of this composite detection system.

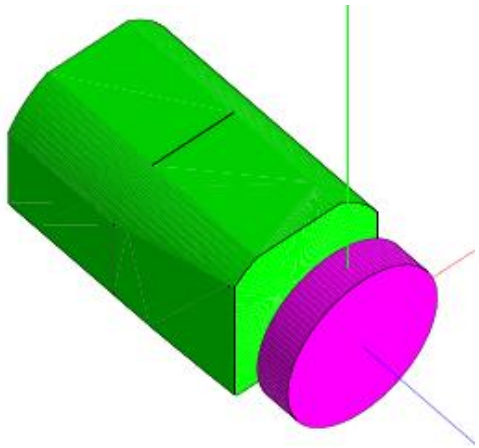

Fig 1: Schematic diag. of the Composite detector

The conceptual design is depicted in the Figure 1. It is expected that the $LaBr_3$:Ce detector will act as the scatter detector, wherein we expect Compton scattering to be dominant while the HPGe where we expect most of the energy to be deposited. We then propose to add the two partial energies to extract the full energy information. The Compton scattering in the first detector would provide us a signal to perform fast timing measurements.

Simulations for this Composite system using GEANT4 are in progress. As shown in the figure the $LaBr_3$:Ce detector had a thickness of 10 mm and the front surface has a diameter of of 43 mm, to coincide with the front tapered face of the HPGe. A single crystal of the Clover detector was used as the second detector. The spacing between the two detector was taken to be 10 mm. The source was positioned at about ~25 cm from the $LaBr_3$:Ce detector. The standard Physics list was used in the simulations.

To validate all the inputs for the simulation, the simulations were performed for a 1.5" x 1.5" cm $LaBr_3$:Ce detectors with the source at 25 cm. The simulated full-energy peak efficiency at 1332 keV obtained was 1.95×10^{-4} Similarly, the full-energy peak efficiency of a single crystal of the Clover under similar conditions was modeled to be 2.54×10^{-4}. These values are in agreement with the reported values [1,2]. This validates the necessary inputs for the simulations.

Fig.II & Fig III depicts the response of the composite system to a simulated 662 and 1332 keV gamma ray.

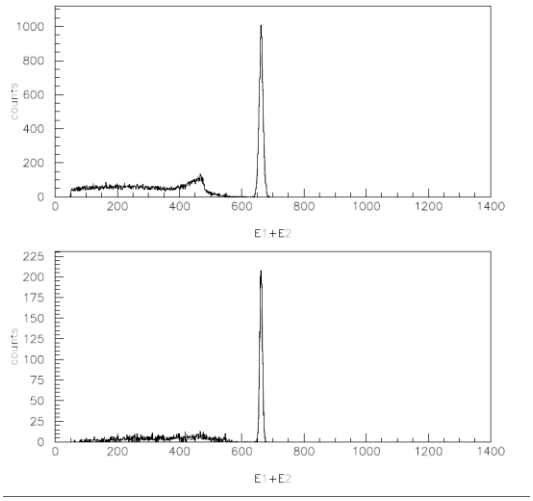

Fig.II : Time correlated sum of $LaBr_3$ & HPGe at 662 keV

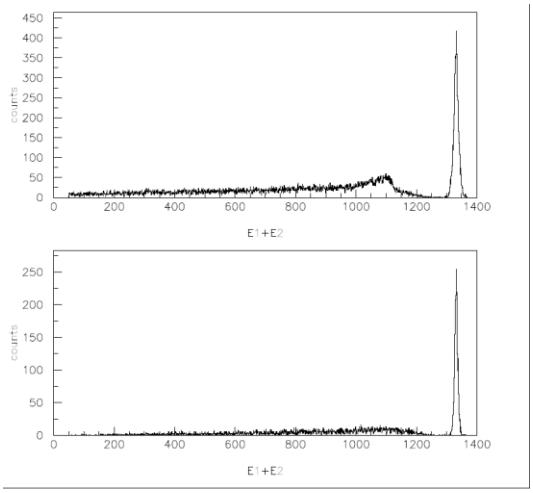

Fig.III : Time correlated sum of $LaBr_3$ & HPGe at 1332 keV

The upper panel in both the figures represents the situation wherein we have set a threshold of 50 keV (Cond1) on the $LaBr_3$:Ce detector to obtain the time correlated sum. The lower panel corresponds to the condition when we have a threshold of 50 keV on the $LaBr_3$ and a 5 keV threshold on the HPGe (Cond2).

Table I summarizes the results of the modeling with a 10 mm gap between the 2 detectors.

	Energy (keV)	P/T %	Resol. (keV)	Full energy εp
Cond1	662	40.1	14.6	2.14E-04
Cond2	662	59.4	10.2	6.02E-05
Cond1	1332	24.5	19.6	9.70E-05
Cond2	1332	40.7	12.0	4.04E-05

We have decreased the gap between the LaBr3 and HPGe to 1mm,and the results are summarized below in table II:

Table II summarizes the results of the modeling with a 1 mm gap between the 2 detectors.

	Energy (keV)	P/T %	Resol. (keV)	Full energy εp
Cond1	662	46.0	13.7	2.60E-04
Cond2	662	64.0	10.3	1.08E-04
Cond1	1332	31.1	17.9	1.29E-04
Cond2	1332	47.4	12.6	7.27E-05

As seen from the figure, there is a considerable increase in the sensitivity of the composite system when used in the add-back mode with a threshold set on both the detectors and if we are able to decrease the separation between the two detectors.

Simulations are in progress to optimize the parameters of the detectors. We also plan to incorporate a thin detector (preferably Si) in front of the entire assembly. This would record the low-energy events that are back-scattered from the $LabBr_3$.

The conceptual design for the readout is being planned using SIPM's, which would allow position information also to be obtained.

References

[1] A Favalli *et al*., Radiation & Measurements 43 (2008) 506.
[2] G Anil Kumar et al., NIM 610 (2009) 522 .